

NAVAL POSTGRADUATE SCHOOL  
Monterey, California

EC 3550

Fiber Optics Experiment 2

4/99 Po

**FIBER OPTIC CONNECTORS**

**Purpose:** To attach a set of ST<sup>1</sup>-type fiber optic connectors to a fiber and to measure the connector loss.

**Equipment:**

ST-style fiber connectors	Exacto knife
Connector housing (ferrule)	Kimwipe tissues
Crimping eyelet	Buehler Fibrmet polisher
Protective cap	Fibrmet discs: 12, 3, 0.3 $\mu\text{m}$
Strain-relief boot	Polishing extender solution
Wire Stripper (14 gauge)	OFTI 353ND epoxy
Cleaning Alcohol	Photodyne 33XLC optical multimeter
1 meter 50/125 fiber cable	Paladin Kevlar cutters
No-Nik fiber stripper (127 $\mu\text{m}$ )	Photodyne 7700XR optical source
Multi-cure heater	Buehler Fibrskope
Crimping tool: OFTI P/N047	Q-tip swab
Rubber gloves	Safety glasses
Material Safety Data Sheets (MSDS) for epoxy, polishing disks, and polishing extender (1 copy available at experiment location)	

**Safety information:**

- The end of optical fiber is very sharp. Be careful not to stick yourself with it.
- All persons in the vicinity of the experiment MUST wear safety glasses (ordinary glasses will also suffice) when the fiber is being cleaved. The end of the fiber will snap off abruptly when cleaved and might fly off in any direction for a meter or two. This poses a potential eye hazard.
- Hazardous materials: The epoxy, the abrasive disks, and the polishing extender are all hazardous materials. They present dangers to the skin, the eyes, and should not be ingested. Material Safety Data Sheets (MSDSs) are provided at the experimental station. *All students MUST familiarize themselves with the contents of these sheets (especially the sections dealing with health hazards, handling, and precautions) BEFORE beginning the laboratory exercise!!* Safety gloves and eye protection MUST be used when handling the epoxy.
- Burn danger: The heater that is used to cure the epoxy will reach temperatures that can cause minor skin burns. The connector will also reach a high temperature after heating in the heater. Be sure to allow for ample cooling time (about five minutes) after removing the connector from the heater before touching it.

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<sup>1</sup>ST is a trademark of AT&T.

**Procedure:** The optical fiber is a cable from Chromatic Technology Inc. The actual fiber is 50/125 graded index fiber with an easily removed buffer material. The fiber loss is specified as 4.5 dB/km at 850 nm, and 3.0 dB/km at 1300 nm. The bandwidth-distance product at 850 nm is 200 MHz·km and at 1300 nm is 500 MHz·km.

Attach connectors to both ends of your length of optical fiber cable using the following procedure:

1. The connector components go on to the fiber cable in reverse order from that in which they will be joined to the connector. First, slide the strain-relief boot, narrow end first, over the end of the optical fiber cable. Continue sliding it down the cable and out of the way of the end on which you will be working. After the strain relief boot is on, do the same with the crimp eyelet, putting it over the cable and clear of the end.
2. Using the gauged wire stripper, remove approximately 1-1/2 inches (or an amount equal to 1-1/2 times the length of the connector) of the gray rubber jacketing material from the end of the fiber cable.
3. Next cut the Kevlar fibers which provide the cable's strength to a length approximately 1/4-th inch beyond the end of the cable jacket using the Kevlar scissors provided for this purpose. The Kevlar fiber will be bound to the connector by squeezing it between the crimp eyelet and the connector body itself, so the length of the Kevlar fiber that remains beyond the end of the cable jacket should be approximately equal to the length of the crimp eyelet.
4. Strip the white plastic buffer from the optical fiber using the 0.010 No-Nik fiber strippers. Remove the buffer material until it extends from the cable jacket the same length as that of the Kevlar fibers. Work carefully, removing about 1/8-th of an inch of material or less at a time. (This minimizes the friction between the fiber surface and the buffer as the buffer is pulled off over it and, consequently, the amount of tension to which the optical fiber is subjected. The length of optical fiber which extends from the end of the cable jacketing should be at a minimum 1/4-th of an inch longer than the connector in order to protect that portion of the fiber which will become the eventual optical surface at the connector face. If the fiber breaks while removing the buffer to a length less than that required, remove more of the jacket and cut back the Kevlar a commensurate amount to free up a sufficient length of fiber.

Note: To allow the fiber strippers to work properly, ensure that the removed buffer material does not remain caught in the teeth of the stripper by blowing it free or tapping the stripper on the table as each piece is removed. Operate the stripper by placing the fiber in the "V" formed by the stripper's teeth and then squeezing the stripper handles firmly until you hear and feel a click as the teeth bite through the buffer. After the buffer is cut, relax your grip on the stripper and gently move it in the direction indicated by the arrow marked on the stripper's head, pulling the buffer material off from the fiber.

5. Remove any residual buffer fragments, grease, etc. from the optical fiber by wiping it clean with a piece of tissue paper dipped in alcohol.
6. Test fit the fiber in the connector. Slowly insert it in through the back end of the connector. You will most likely encounter resistance as the connector body narrows

internally to the 125  $\mu\text{m}$  diameter of the connector ferrule. Gently withdraw the fiber a small amount and then reinsert it, repeating this motion as often as required to get the fiber aligned properly so that it will slip through the tiny hole in the connector. Do *not* try to force the fiber through the connector as that will most likely break it.

When the fiber is successfully inserted into the connector ferrule, slide the connector down until it butts up against the cable jacket. At this point ensure that the fiber extends at least 1/4-th of an inch from the connector face. If it is not long enough, remove the connector and repeat the previous steps to remove more of the jacket, Kevlar, and buffer until sufficient fiber length is achieved.

7. Once the fiber is stripped and test fitted, fill the connector with epoxy by inserting the epoxy syringe into the connector through the back as far as it will go and depressing the plunger. The epoxy is very thick and flows slowly out of the syringe. Do not try to force epoxy out at a faster rate by applying excessive pressure on the plunger. (This will result in blowing the needle off the syringe and in epoxy flowing everywhere but into the connector.) Continue to allow epoxy to flow into the connector until it is seen to reach the top.
8. With epoxy in the connector, reinsert the fiber using the procedure of step 6. Ensure that the Kevlar fibers remain on the outside of the connector when the fiber is completely inserted.
9. Hold the connector down against the cable jacket and slide the crimping eyelet up over the Kevlar fibers and knurled portion of the connector body. While keeping the connector firmly butted up against the end of the cable jacket, crimp the eyelet over the Kevlar and the connector using the B portion of the OFTI 047 crimp tool. It is important that the connector and the cable jacket be securely butted together before the crimp is made so that there will be no slack in the Kevlar fibers after the connector is attached. The connector is designed so that any stress on the connector/cable assembly will be borne by the connector and the Kevlar fibers, with the fiber itself being allowed to “float” free inside the assembly. (Since the fiber will be epoxied into the connector, it will only float in the sense that, if properly connected, it will not be subjected to the longitudinal stresses which may be applied to the exterior components.) If, however, there is any slack in the Kevlar strength members which permits connector movement away from the cable, the end of the fiber which is epoxied into the connector may be stretched, leading to possible breakage of the fiber inside the connector. Test the connection after crimping by gripping the cable and the connector and gently attempting to pull them apart. Observe the fiber which extends out of the connector to detect any movement which will be translated to stress on the fiber once the end is epoxied in place. If it is found that the fiber moves in and out excessively (i.e., more than 1/8-th inch) as the cable/connector assembly is stressed, then either the connector will have to be redone, or steps will have to be taken to ensure that the cable is not stretched at the connector. (For the purposes of this lab, it will suffice to know that the fiber in the cable is potentially susceptible to breakage if pulled and to be careful with it. A connection in the field where the environment cannot be controlled, however, would require that a new connector be put on to protect the fiber from stresses which may break it.)
10. Apply a small hemispherical bead of epoxy to the end of the connector around the

protruding fiber. Grasp the connector firmly with one hand and the cable jacket with the other and pull gently. This action helps to seat the fiber and allows a wetting action inside the fiber tip itself. Place the connector carefully into the fixture in the epoxy curing oven. Once cured, the bead of epoxy will prevent the end of the fiber from being broken off below the face of the connector. Until the epoxy is hardened, however, care must be taken to ensure that the fiber is not broken since, if it breaks below the connector surface, it will be impossible to polish the fiber end to the smooth surface required to couple light efficiently into and out of the fiber. Cure the epoxy for about 5 minutes in the oven. When hardened, the epoxy will change from yellow to a dark reddish-brown color.

11. Remove the connector from the oven after the curing is completed. *BE CAREFUL! IT'S HOT!* Allow it to cool for a few minutes before continuing your work.
12. Slide the strain relief boot up over the connector. Put on your safety glasses and cleave the excess fiber protruding from the epoxy bead using the Exacto knife.
13. Polish the face of the fiber. Prepare the Buehler Fibrmet Polisher by placing a 12  $\mu\text{m}$  grit disk (yellow) on the right wheel. (The left wheel is machined to a tighter tolerance and is used for final polishing only.) Wet the disk by spraying on the Polishing Extender Fluid (white solution) and spreading it evenly over the surface using a Q-Tip. Insert the connector into the fixture, pull the polishing arm out, and rotate it down until the connector rests on the disk. Turn the power switch on and allow a minimal amount of passes to remove the epoxy bead from the face of the connector. (Do not overpolish with this grit as it could score the face of the connector, increasing connector losses. A light glaze of epoxy remaining on the surface is satisfactory at this step.) Return the arm back to the post.

Peel the used disk off the wheel and attach a 3  $\mu\text{m}$  grit disk (gray) to the right wheel. Wet this disk with the polishing solution and repeat the polishing procedure. Allow ten passes or so to remove the epoxy glaze. (A small amount of connector metal will be removed with this grit.) Return the arm to the post position. (Leave the polishing disk on the wheel in case further polishing of this connector is later found to be required.)

Attach the 0.3  $\mu\text{m}$  grit disk (white) to the *LEFT* wheel, wet the surface with the polishing extender, and polish the connector as in previous steps. Allow the connector to make 15-20 passes over the polishing wheel with this grit.

14. Clean the connector face with a Q-Tip and alcohol. Use one end of the Q-tip to apply the alcohol and the other end to dry the connector. Allowing the alcohol to air-dry on the connector will leave a residue on the fiber face which could affect coupling efficiency or mask other defects when inspecting the fiber.

Examine the surface of the fiber with the Fiberscope. (The focus can be adjusted using the rectangular knobs on the side.) The optical surface of the fiber should be smooth and free of cracks or scratches. If scratches are found, further polishing with the 3 and 0.3  $\mu\text{m}$  disks may be able to remove the defects.

**Connector Loss Measurement:** After you have applied connectors to both ends of your fiber sample, you are ready to measure the losses due the connectors.

1. The Photodyne optical multimeter measures the optical power incident on the attached detector. The unit can be used to measure absolute power (in watts) or relative power (in dBm). We will use it in the latter fashion.
2. Set up the Photodyne 7700XR optical source to operate as a 1 kHz pulsed AC source.
3. Connect the provided reference fiber pigtail between the source and the power meter and measure the power out of the end of this length of fiber in dBm.
4. Add your fiber with its newly installed connectors in between the reference pigtail and the power meter using the optical fiber mating coupler provided. Measure the received power in dBm. The difference in readings (in dB) is due to the introduction of a connection between the reference fiber and your fiber, the attenuation within your fiber, and the different coupling efficiency between your exit connector and the power meter detector. Compute the loss from your two power readings.
5. Reverse your fiber, switching the position of the entrance and exit connectors, and repeat the loss measurement.
6.
  - (a) Compute the loss due to attenuation within the fiber using the data given above. (Although the source wavelength we are using is 820 nm, we will use the fiber properties given for 850 nm operation since the manufacturer does not specify the loss at 820 nm.)
  - (b) If there was any difference in the loss measurements made when your cable was reversed, explain why this occurred. If there was no difference noted, postulate on the factors which could have caused such a condition.
  - (c) Calculate the measured loss per connector pair for both orientations.

You may either keep your fiber or turn it in to the lab engineer for possible entry into our Fiber Optic Hall of Fame. (Fiber pigtails with average connector losses in excess of 2 dB need not apply.)

**Connector Cost:** Using the course web site, find the link to FIS (Fiber Instrument Sales). Find the cost of the connector that we are using (FIS Model F1-006), the maximum and minimum cost of a multimode ST-style connector, and the maximum and minimum costs of a single-mode ST-style connector.

**Report:** Submit a brief report summarizing your observations and loss measurements. This report is due within one week of completing the experiment.